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NOTE ON ANIMAL DISTRIBUTION FOLLOWING A HARD WINTER.

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LAKE FOREST COLLEGE.

For the past six summers I have been studying the distribution of littoral invertebrates near Woods Hole, Mass., in connection with a teaching appointment in the invertebrate course in the Marine Biological Laboratory. The work has been largely done in connection with the class trips which give a good opportunity for general collecting in that each of the six or seven instructors has from six to eight students working with him in the field. As a result of the class collecting during this period, there are over 190 species of invertebrates listed in the class catalogue that have been taken alive on student excursions.

Something of the thoroughness of the collecting may be seen from the fact that this work has added two new species to the faunal catalogue of this well-studied region: In 1915 Dr. T. S. Painter took a living specimen of *Arca ponderosa* (Say) in dredging off Naushon in Vineyard Sound. The animal was taken on the sand dollar grounds off Tarpaulin Cove in about six fathoms of water. Regarding this species the Biological Survey¹ says: "Verrill has expressed doubts as to whether *Arca ponderosa* lives in this region since no living specimen has been taken north of Cape Hatteras. Mr. G. M. Gray likewise reports that he has never taken this species alive. Dr. Dall informs us, however, that the National Museum contains a fresh valve, retaining the epidermis, taken in Vineyard Sound in 1870; and Mr. C. M. Johnson reports that he has found more than one shell of this species still bearing evident traces of the hinge ligament and epidermis, on a beach near Chatham Light." The extensive dredgings of the survey yielded only a few shells. The range is usually given as extending from Provincetown to Yucatan.

¹ Biological Survey of the Waters of Woods Hole and Vicinity by Francis B. Sumner, Raymond C. Osborn, and Leon J. Cole. Bull. Bureau of Fisheries, Vol. 31. Two parts.

Miss Eleanor Bach in 1916 found a specimen of *Halicystus auricula* (Clark) attached to eel grass in low water near the old Vineyard Haven wharf where it had apparently been washed up with algæ. This is a northward ranging species with a range from Cape Cod to Greenland.

A slight amount of preliminary collecting in the latter part of June, 1918, showed that the fauna was noticeably changed from the preceding year and that the change was decidedly greater than the usual yearly fluctuation. The preceding winter had been unusually severe and this offered an hypothesis for the cause of the unusual changes in the abundance of some animals.

The water temperatures have been taken for a number of

TABLE I.

Showing the Temperatures at Noon off the U. S. Fish Commission Wharf at Woods Hole, for the Four Winter Months of 1916-17 and 1917-18.

1916-17.					1917-18.			
Dec.	Jan.	Feb.	Mar.		Dec.	Jan.	Feb.	Mar.
46.5	32	33	32.5	1	41	29.5	30	32
45	33.5	32	32.5	2	40.5	29.5	30	32
44.5	34.5	30	32	3	39	30	30	32
45	34.5	30	32	4	39.5	29.5	30	31.5
46.5	34.5	30	32	5	39.5	30	30	32
46	35.5	30	32	6	39	30	30	32.5
44.5	35.5	30.5	32.5	7	38.5	31	30	32
44.5	35	31	33.5	8	37	30.5	30	31.5
44.5	36	31.5	34	9	38	30	30	31.5
44	36.5	31	33.5	10	36	30.5	30	32
43	36	31.5	33	11	35	31	30	31.5
44	33	30	35.5	12	34.5	31	30	31.5
42.5	33.5	30	33.5	13	34	30	31	32
42	35	30	34	14	34.5	30	31	31
41	33.5	30	34.5	15	33	30	31.5	31.5
39.5	33.5	31	34.5	16	33	30.5	31.5	30.5
39.5	32.5	31	34.5	17	33	30	31.5	30.5
38	33	31	35.5	18	33.5	30	31	31.5
37	32.5	31	34	19	33	30.5	31.5	32.5
36	32.5	31.5	34	20	33.5	30	32	32.5
37	32.5	31	34	21	34.5	30	31	33
37	33	31	34.5	22	34.5	30.5	31	32.5
37	32.5	30.5	34	23	33	30	31	34
36	32.5	31.5	35.5	24	33	30	31	33
36.5	32.5	31.5	36	25	34.5	30.5	31	34
35	32	32	37.5	26	33	30.5	32	34
35	31	32	37.5	27	32.5	30.5	31	34.5
36.5	31	31	38.5	28	32.5	30.5	32	34.5
35	31.5		38	29	31	30		36
34	33		38	30	29.5	30		36
32.5	32.5		39	31	29.5	28		36.5

years off the wharf of the U. S. Fish Commission at Woods Hole. The manuscript notes of the daily readings for the winters of 1916-17 and 1917-18 were made accessible through the kindness of Superintendent W. H. Thomas. The noon temperatures for the months of December, January, February and March of these years are given in Table I. From December 29, 1917, to March 19, 1918, a period of 80 days, the noon temperature did not rise above freezing, except on March 6, when it reached 32.5° F.

These temperatures are summarized in Table II., together with a similar summary for the period of 1902-06 taken from

TABLE II.

Showing Mean, Maximum and Minimum Noon Temperatures off the Fish Commission Wharf at Woods Hole, Mass.

Period.	December.	January.	February.	March.
1902-1906. Mean	37.2	32.3	31.0	35.64
Minimum	31.5	28.0 ¹	28.0 ¹	29.5
Maximum	47.5	39.5	37	44
1916-1917. Mean	39.9	33.4	30.9	34.3
Minimum	32.5	31	30	32
Maximum	46.5	36.5	33	39
1917-1918. Mean	35.1	30.1	30.75	32.7
Minimum	29.5	28 ¹	30	30.5
Maximum	46.5	31	32	36.5

¹Inexact; below the freezing point of water.

the Biological Survey. It will be noted that the mean temperature for each of the months considered is less than for the corresponding month of the preceding year or of the five-year interval; that February, the coldest month, is only slightly below that of the other years, but that the other months are all decidedly lower and that the cold weather continued practically through March.

The mean noon temperature for the 121 days listed, in the five-year period from 1902-06 was 34.4 degrees. In 1916-17 there was a mean temperature of 35.5 degrees during this winter period, while for 1917-18 the mean temperature was only 33.3 degrees. This gives a temperature deficit of 1.1 degrees per day when compared with the longer period, and of 2.2 degrees when compared with the preceding winter.

The effect of an usually cold winter should be most marked

upon animals near the northern limit of their geographical range. The result of an inquiry as to whether or not such animals were affected is shown in the list given as Table III. The list is made from the class list of invertebrates whose distribution, as shown in Pratt's Manual of Common Invertebrate Animals, is that of southern ranging animals. By "southern ranging" is meant that the known geographical range extends twice as far south as north of the point under consideration. The frequency data is based principally on my own experience in the field assisted by that of Mr. J. S. Kostir, of Ohio State University, who has collected over the same ground for the last two summers.

TABLE III.

A List of Species, that are South Ranging according to Pratt. Taken by the Invertebrate Class of the Marine Biological Laboratory. The Comments in the Last Column Give the Frequency Data as Compared with the Preceding Summer.

Species

Porifera:	Range	Frequency
<i>Cliona celata</i> (Grant).....	S. Ca.—Maine.	Fewer.
<i>Chalina arbuscula</i> (Ver.).....	N. Ca.—Cape Cod.	Fewer.
<i>Microciona prolifera</i> (Ellis and Solander).....	S. Ca. ² —Cape Cod.	Fewer.
Coelenterata:		
<i>Pennaria tiarella</i> (Ayres).....	Fla.—Maine.	Fewer.
<i>Schizotricha tenella</i> (Ver.).....	Beaufort, ¹ N. C.—Marthas Vineyard.	No change.
<i>Dactylometra quinquecirrha</i> (Desor).....	Tropics—Vineyard Sound.	Comparison unfair.
<i>Sagartia luciae</i> (Ver.).....	Florida ² —Cape Cod.	Fewer.
<i>Sagartia leucolena</i> (Ver.).....	N. Ca.—Cape Cod.	More.
<i>Eleoactis producta</i> (And.).....	S. Ca.—Cape Cod.	Fewer.
<i>Astrangia danae</i> (Ag.).....	Fla.—Cape Cod.	Fewer.
Nemertini:		
<i>Micruri leidyi</i> (Ver.).....	N. J.—Cape Ann.	Fewer.
<i>Cerebratulus lacteus</i> (Leidy).....	Fla.—Maine.	Fewer.
Echinoderma:		
<i>Asterias forbesi</i> (Desor).....	Common south of Cape Cod	
	Rare north to Maine.	More small.
<i>Ophioderma brevispina</i> (Say).....	South from Cape Cod.	Fewer.
<i>Arbacia punctulata</i> (Gray).....	Yucatan ² —Cape Cod.	Fewer.
<i>Thyone briareus</i> (Lesueur).....	South from Vineyard Sound.	No change.
Annelida:		
<i>Sthenelais leidyi</i> (Quatr.).....	N. Ca.—Mass. Bay.	No change.

<i>Podarka obscura</i> (Ver.).....	G. of Mexico—Cape Cod.	Fewer.
<i>Nereis limbata</i> (Ehlers).....	S. Ca.—Maine.	No change.
<i>Platynereis megalops</i> (Ver.).....	Beaufort, N. C.—Cape Cod.	Comparison unfair.
<i>Diopatra cuprea</i> (Bosc.).....	S. Ca.—Cape Cod.	No change.
<i>Lumbrinereis tenuis</i> (Ver.).....	Va.—Mass.	No change.
<i>Arabella opalina</i> (Ver.).....	West Indies—Maine.	No change.
<i>Glycera americana</i> (Leidy).....	S. Ca.—Cape Cod.	No change.
<i>Scopelos robustus</i> (Ver.).....	N. Ca.—Cape Cod.	No change.
<i>Chaetopterus pergamentaceus</i> (Cuv.)..	N. Ca.—Cape Cod.	No change.
<i>Cirratulus grandis</i> (Ver.).....	Va.—Cape Cod.	No change.
<i>Pista palmata</i> (Ver.).....	Va. ¹ —Vineyard Sound.	Comparison unfair.
<i>Amphitrite ornata</i> (Leidy).....	N. Ca.—Cape Cod.	No change.
<i>Polycirrus eximeus</i> Leidy).....	N. Ca.—Cape Cod.	No change.
<i>Pectinaria gouldi</i> (Ver.).....	N. Ca.—Maine.	No change.
<i>Maldane urceolata</i> (Leidy).....	N. Ca.—Cape Cod.	No change.
<i>Arenicola cristata</i> (Stimp.).....	Fla.—Cape Cod.	No change.
<i>Trophonia affinis</i> (Leidy).....	N. J.—Vineyard Sound.	Comparison unfair.
<i>Clymenella torquata</i> (Leidy).....	N. Ca.—Bay of Fundy.	No change.
<i>Sabella microphthalmia</i> (Ver.).....	N. Ca.—Cape Cod.	Fewer.
<i>Hydroides hexagonus</i> (Bosc.).....	Fla.—Cape Cod.	Fewer.
<i>Sabellaria vulgaris</i> (Ver.).....	N. Ca.—Cape Cod.	Fewer.
Bryozoa:		
<i>Bugula turrila</i> (Desor).....	N. Ca.—Casco Bay.	No change.
<i>Schizoporella unicornis</i> (Johnston)...	S. Ca. ² —Mass. Bay.	Fewer.
Arthropoda:		
<i>Balanus eburneus</i> (Gould).....	W. Indies—Mass. Bay.	No change.
<i>Orchestria agilis</i> (Smith).....	Ranges south to Florida.	No change.
<i>Talorchestia longicornis</i> (Say).....	N. J.—Cape Cod.	No change.
<i>Haustorius arenarius</i> (Slabber)....	Ga.—Cape Cod.	No change.
<i>Caprella geometrica</i> (Say).....	Va.—Cape Cod.	Fewer.
<i>Sphaeroma quadridentatum</i> (Say)....	Fla.—Cape Cod.	Fewer.
<i>Chiridotea caeca</i> (Say).....	Fla.—Nova Scotia.	Comparison unfair.
<i>Palæmonetes vulgaris</i> (Say).....	Fla.—Mass.	No change.
<i>Pagurus longicarpus</i> (Say).....	S. C.—Maine.	No change.
<i>Pagurus pollicaris</i> (Say).....	Fla.—Maine.	No change.
<i>Pagurus pollicaris</i> (Say).....	Fla.—Maine.	No change.
<i>Hippa talpoida</i> (Say).....	Fla. ¹ —Cape Cod.	Fewer adult.
<i>Libinia emarginata</i> (Leach).....	Fla. Maine.	Fewer.
<i>Libinia dubia</i> (Milne-Ed.).....	Fla.—Cape Cod.	More.
<i>Panopeus sayi</i> (Smith).....	Fla.—Mass.	No change.
<i>Callinectes sapidus</i> (Rath.).....	La.—Cape Cod.	Fewer.
<i>Ovalipes ocellatus</i> (Herbst).....	G. of Mex.—Cape Cod.	Fewer.
<i>Carcinides maenas</i> (L.).....	N. J. —Cape Cod.	Fewer.
<i>Pinnotheres maculatus</i> (Say).....	S. C.—Cape Cod.	No change.

<i>Uca pugilator</i> (Bosc.).....	Fla.—Cape Cod.	No change.
<i>Limulus polyphemus</i> (L.).....	Fla.—Nova Scotia.	More.
<i>Tanystylum orbiculare</i> (Wilson).....	Va. ¹ —Martha's Vineyard.	Comparison unfair.

Mollusca:

<i>Chatopleura apiculata</i> (Say).....	Fla.—Cape Cod.	No change.
<i>Melampus lineatus</i> (Say).....	Tex.—N. Eng.	No change.
<i>Natica duplicata</i> (Say).....	Mex.—Mass. Bay.	No change.
<i>Crepidula fornicata</i> (L.).....	S. Am.—Nova Scotia.	No change.
<i>Crepidula convexa</i> (Say).....	Fla.—Nova Scotia.	No change.
<i>Crepidula plana</i> (Say).....	Tex.—Maine.	No change.
<i>Bittium alternatum</i> (Say).....	N. J.—Mass. Bay.	No change.
<i>Cerithiopsis greeni</i> (Adams).....	Tex.—Mass. Bay.	No change.
<i>Eupleura caudata</i> (Say).....	Fla.—Cape Cod.	Comparison unfair.
<i>Urosalpinx cineros</i> (Say).....	Fla.—Mass. Bay.	No change.
<i>Columbella lunata</i> (Say).....	Fla.—Mass. Bay.	No change.
<i>Columbella avara</i> (Say).....	Fla.—Cape Cod.	Fewer.
<i>Nassa trivittata</i> (Say).....	Fla.—G. of St. Law.	No change.
<i>Nassa obsoleta</i> (Say).....	W. Fla.—G. of St. Law.	No change.
<i>Busycon carica</i> (L.).....	G. of Mex.—Cape Cod.	Fewer.
<i>Busycon canaliculatum</i> (L.).....	G. of Mex.—Cape Cod.	Fewer.
<i>Anomia ephippium</i> (L.).....	W. Ind.—Nova Scotia.	Fewer.
<i>Arca pexata</i> (Say).....	Fla.—Maine.	Fewer.
<i>Arca ponderosa</i> (Say).....	Fla.—Cape Cod.	Comparison unfair.
<i>Arca transversa</i> (Say).....	Fla.—Cape Cod.	Fewer.
<i>Ostrea virginica</i> (Gmelin).....	G. of Mex.—Mass.	Fewer.
<i>Pecten irradians</i> (Lam.).....	Tex.—Cape Cod.	Fewer adult.
<i>Tellina tenera</i> (Say).....	W. Fla.—G. of St. Law.	No change.
<i>Cumingia tellinoides</i> (Conrad).....	Fla.—Cape Cod.	No change.
<i>Venus mercenaria</i> (L.).....	Tex.—G. of St. Law.	No change.
<i>Petricola pholadiformis</i> (Lam.).....	Tex.—G. of St. Law.	Fewer.
<i>Laevicardium mortoni</i> (Conrad).....	W. Fla.—Nova Scotia.	Fewer.
<i>Clidiophora trilineata</i> (Say).....	Tex.—Nova Scotia.	Comparison unfair.

Chordata:

<i>Dolichoglossus kowalevskyi</i> (A. Agas- siz).....	Beaufort, N. C.—Mass. Bay.	No change.
<i>Styela partita</i> (Stimp.).....	N. C.—Mass. Bay.	Fewer.
<i>Molgula manhattanensis</i> (DeKay)...	N. C.—Casco Bay.	Fewer.
<i>Perophora viridis</i> (Ver.).....	Bermuda ¹ —Vineyard Sound.	Fewer.
<i>Amaroucium pellucidum</i> (Leidy)...	N. C.—Vineyard Sound.	No change.
<i>Amaroucium stellatum</i> (Ver.).....	N. C.—Cape Cod and north.	No change.
Summary: Fewer, 36; no change, 45; more, 5; unfair comparison, 9.		

¹ Range taken from Biological Survey.² Discussed in text following.

In order to check up on this data I asked Mr. G. M. Gray for a list of the forms that had proven difficult to obtain during the 1918 season. I did not ask him to refer to his records because only those animals that had been so difficult to obtain that they were well fixed in his mind were wanted. This group of animals with their distribution is given as Table IV. An inspection of the table will show that in each case the animals are southern ranging forms with Woods Hole near the northern limit of their range.

TABLE IV.

Listing the animals which Mr. G. M. Gray found to be especially difficult to obtain in the summer of 1918 as compared with his experience in other years.

<i>Sagartia luciae</i> (Ver.)	Fla.—Mass. Bay.
<i>Astrangia danæ</i> (Ag.)	Fla.—Cape Cod.
<i>Arbacia punctulata</i> (Gray)	Yucutan—Cape Cod.
<i>Hippa talpoida</i> (Say)	Fla.—Cape Cod.
<i>Callinectes sapidus</i> (Rath)	La.—Cape Cod.
<i>Styela partita</i> (Stimp.)	N. C.—Mass. Bay.
<i>Perophora viridis</i> (Ver.)	Bermuda—Vineyard Sound.

Arbacia punctulata had been particularly abundant in 1917. Small specimens were taken from rocks at Kettle Cove, at the Buzzard Bay entrance to Northwest Gutter, near Quissett and at North Falmouth. In all these places they came up almost to the low tide limit. In the deeper water they had again appeared in numbers on what the collecting crew called "the old *Arbacia* grounds" off Nobska Light. In 1918 none were taken by the class except in dredging in Vineyard Sound off Tarpaulin Cove, and then only a few small individuals. In fact during all the summer, in place of the usual abundance of large specimens, Mr. Gray was able to furnish only relatively few small *Arbacia*.

Sagartia luciae, usually the most abundant actinian in the Woods Hole region, was almost wanting at the beginning of the summer in 1918. In only one place visited throughout the summer was this small anemone present in anything like its usual abundance. This was at Kettle Cove, where in the protected tide pools, the rocks were covered in about their normal fashion. On the exposed parts of Kettle Cove, as everywhere else, the rocks were practically bare. Pratt gives the distribution of this species as Long Island Sound to Massachusetts Bay and further

north. The Biological Survey says that it first appeared in New Haven in 1892 and at Woods Hole in 1898. Professor Verrill believed that this *Sagartia* was introduced near New Haven on oysters from the south. Professor Parker states that it is a southern ranging species.

One more particular instance of a marked decrease in abundance was that of the red sponge, *Microcion prolifera*. In the early part of the season this sponge was almost absent from the wharf piles. Later they became more abundant.

In a number of instances the cold weather killed off the animals living in shallow water and left only those in deeper water. This tendency has already been mentioned in the case of *Arbacia*. It was also marked with the encrusting bryozoa as, *Schizoporella unicornis*.

In Table III. the data concerning *Platynereis* is listed as being insufficient to furnish a fair comparison. As a matter of fact none were taken this year but usually the number taken in the class collecting has been small and it is possible that we overlooked them this year. However, Dr. E. E. Just, who has been collecting swarming annelids for some years, reported that up to August 1 he had taken no *Platynereis* in his night collections although usually they are abundant by that time. *Autolytus cornutus* (A. Agassiz) was also lacking in his collections at that date although normally present. Unlike the other species this annelid is northerly ranging. It is found from New Jersey to the Bay of Fundy. Dr. Just also reported that the cold spring had affected the periodicity¹ of the early runs of *Nereis limbata* in a way wholly comparable with other late springs.

It is to be expected that the negative effect of a cold winter would be more noticeable than its positive effect. However, two northerly ranging species were present in decidedly increased numbers in the collecting. The more noticeable of these was the sponge, *Leucosolenia botryoides* (Bow.). Pratt gives its range as from Martha's Vineyard to the Gulf of St. Lawrence. Usually we have taken it to some extent in the class collecting on wharf pilings, but this year it was very abundant there and was found

¹ Lillie, F. R., and Just, E. E., 1913, "Breeding Habits of the Heteronereis. Form of *Nereis limbata* at Woods Hole, Mass.," BIOL. BULL., 24, pp. 147-169.

in some abundance on rocks, such as those at the Buzzard Bay entrance to Northwest Gutter.

The blood starfish, *Henricia sanguinolenta* (O. F. Müller), distributed from Cape Hatteras to Greenland and reported as common north of Cape Cod, was decidedly more abundant this year than usual.

The effects of the unusually cold winter on the abundance of the animal life may be due to one or all of the following factors:

1. To the temperature deficit, regardless of the duration of the cold weather. In this case the deficit amounted to 133 degrees when the winter months were compared with those of the five year period of 1902-06.

2. To the long-continued cold weather (practically 80 days at or below freezing).

3. To the fact that the cold weather began relatively early, or that it lasted relatively late, without regard to the temperature in the mid-winter interval.

Of these possibilities, I am inclined to regard the second and third as furnishing the cause for the observed change on the animals, with the fact that the cold weather lasted well through March as the most important factor. This is supported by the February temperatures, which were practically the same for the three periods listed, so the temperature for this month could have made little difference, and by general experience that a "late spring" gives some approach to the conditions found this summer.